VOLUME XLI NUMBER 4 WHOLE NUMBER 363

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS:

C. S. BEALS
Acting Dominion Astronomer
Ottawa

J. A. PEARCE
Dominion Astro-physicist
Victoria, B.C.

A. THOMSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(Ten numbers per year)

April, 1947

PRINTED FOR THE SOCIETY
TORONTO: 3 WILLCOCKS ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

Vol. XLI, No. 4 APRIL, 1947 WHOLE No. 363

Articles PAGE

Siderite Meteorites and their Chemistry (With Plates III, IV) ..... *R. P. Graham* 129

The Martian Merry-go-Round ..... *D. W. Rosebrugh*

The Unidentified Blue-green Bands in certain N-type Stellar Spectra (With Plate V) ..... *Andrew McKellar* 147

Observation of the Giacobinid Meteors at the David Dunlap Observatory (With Plate VI) ..... *John F. Heard* 161

Out of Old Books

Halley and the Brightness of Venus ..... *Helen Sawyer Hogg* 163

Notes and Queries

Fire-walking ..... *C. A. C.* 167

Upon request, made previous to publication of article, contributors will be supplied free with twenty-five copies of the sheets containing the article attached to a printed cover.

Extra copies about as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$5 50	$9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Address of Editors: David Dunlap Observatory, Richmond Hill, Ontario.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 3 Willcocks St., Toronto 5, Ontario.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

NOTICE FROM THE GENERAL TREASURER

Those who have already received the OBSERVER'S HANDBOOK for 1947, but are intending to resign their membership at the end of 1946, are asked to send the 25c payment (coin in card) to their local treasurer or to the General Treasurer, 3 Willcocks St., Toronto 5.

PRINTED IN CANADA

PLATE III

Figure 1

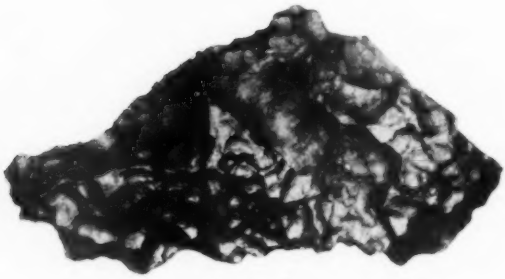


Figure 2

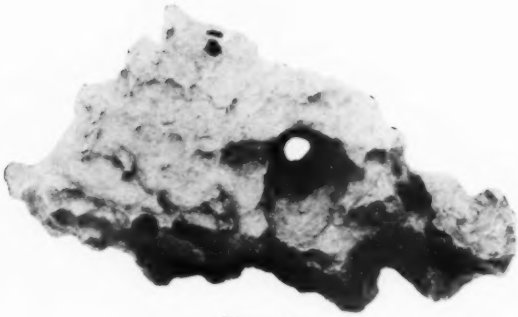


Figure 3

PLATE IV

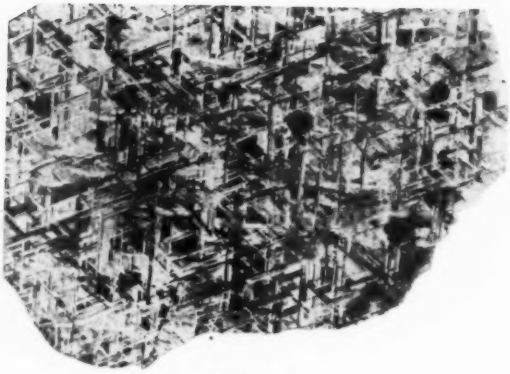


Figure 4

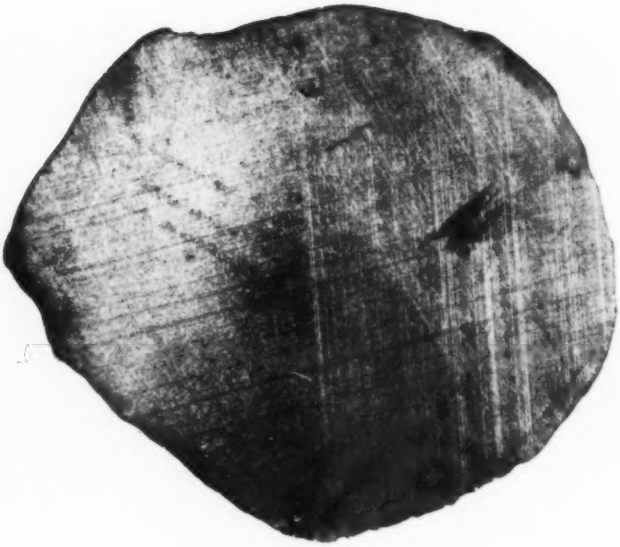


Figure 5

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XLI, NO. 4 APRIL, 1947 WHOLE NO. 363

SIDERITE METEORITES AND THEIR CHEMISTRY*

By R. P. GRAHAM

(With Plates III, IV)

HISTORY

IT is common knowledge that many ancient peoples buried with their dead the valued possessions of the deceased. It may not be well known that objects made from iron meteorites have had a place in such funeral rites. The meteoritic origin of an iron relic dating from possibly 3100 B.C., found in a royal tomb at Ur in ancient Sumeria, has been proven by chemical analysis;[90] similarly the iron in the beads of a necklace, probably five or six thousand years old, found in Egypt in a predynastic grave at Gerzeh,[20] has been shown to be meteoritic.[26] Part of an iron finger-ring found in a grave in Sicily, dating from perhaps the transition period of the Stone to the Metal Age, is believed[118] to be wrought from a meteorite, but apparently this fragment has not been examined chemically.

Iron dating from the Middle Minoan period (circa 1800 B.C.) and regarded by Rickard[90,91] as almost certainly of meteoritic origin has been uncovered at Knossos;[42] it is implied by Wells[114] that iron in the form of meteorites was known in Crete as early as 2500 B.C. but there does not appear to be support for this view in the classical work on early Cretan civilization by Evans.[30] Lord Rayleigh considers[89] that the references in Homer to iron[53] as a rare and precious substance are best explained by presuming that the only iron known was that obtained from meteorites. In this connection it is very interesting to note that there is good reason to believe[118]

*Based on a paper presented March 1, 1945, before the Hamilton Centre of the Royal Astronomical Society of Canada. The author is Assistant Professor of Chemistry in McMaster University, Hamilton, Ontario—Editorial note.

that a dagger found by Schliemann at Hissarlik (the site of Troy) contains meteoritic iron.

There are unmistakable references to meteorites in early writings, e.g., a Hittite text of the fourteenth century B.C. refers to "black iron of heaven from the sky."[93] Certain passages[54] in the Bible may be interpreted as allusions to the fall of meteorites and in one instance[1]—"the image which fell down from Jupiter"*—a meteorite must almost certainly be meant.[36] Meteorites are mentioned by Livy and Pliny and Plutarch; ancient Chinese writings record meteoritic falls dating from prior to 600 B.C.[19,87]

It has been established that at least some of the peoples of antiquity understood the ultra-terrestrial character of what we to-day call meteorites. For example, in Phrygia over two thousand years ago a mass fell from the sky and was on this account worshipped there for many generations;[35] it was taken to Rome about two hundred years before the Christian era, and was an object of worship in that city for over five hundred years.[67] That certain of the inhabitants of the Near Eastern ancient world were aware of the heavenly origin of meteorites is indicated by the significance of the word or symbol they used to designate iron.[91,113] A realization that meteorites have a celestial source has not, however, prevailed throughout the period of man's written history. This enlightened concept has at times been accorded scepticism and ridicule, even by men of learning within the last two hundred years.** Doubt regarding the extra-terrestrial

*This is the translation given in the American Standard Version (1901), in the English Revised Version (1881) and in the King James Version (1611), and is similar to that of Tyndale (1534) "the ymage which came from heven." Translations close to these have been made by modern scholars, e.g., Weymouth, Moffat and Goodspeed. The most interesting rendering from the point of view of the present paper is contained in the new Revised Standard Version (1946): "the sacred stone that fell from the sky."

**For example, it has been stated[50,62,69,113] (although the story may be apocryphal[64]) that after the meteoritic fall of stones in Connecticut in 1807 had been affirmed by Kingsley and Silliman of Yale, President Thomas Jefferson said that he found it easier to believe that two Yankee professors would lie than that stones should fall from heaven. Stütz, a famous Austrian mineralogist, is believed[37] to have remarked, concerning a reported fall of iron in 1751, that "in our time it would be unpardonable to consider such fairy tales even probable." The Swiss geologist J. André de Luc is quoted[64] as saying that even though he should see a meteorite fall, he would not believe it. Lavoisier, the great chemist, subscribed (in a report to the French Academy of Sciences in 1772) to the belief that stones reportedly from the sky were ordinary stones that had been struck by lightning.[64,69,84,89]

origin of meteorites was dispelled from the minds of scientific men of the Western world only about one hundred and fifty years ago, largely as a result of the work of Chladni in 1794 and Biot in 1803.

By diverse peoples and at various times meteorites have been regarded as messages from the gods, have been considered as sacred objects worthy of reverence and worship, have been looked upon as evil omens or bewitched personages, have given rise to fear and superstition, have been regarded as miracles of, or a means of punishment by the Christian God, and have been thought of as the work of devils or infernal spirits.[37,44,64,67,69]

A few of the curious superstitions and practices induced by meteorites may be cited.[69] An iron meteorite which fell near Elbogen, Bohemia, around the year 1400 was regarded by the people of the locality as the metamorphosed remains of a tyrannical court official who had died some little time before the fall of the meteorite. Again, in the excavation of a Montezuman ruin in Mexico there was found a one-and-a-half ton iron meteorite wrapped in mummy cloth of a type used for honourable burials. A reported[38,61] practice of the Kaffirs of South Africa is, or used to be, the exposure of a new-born baby to the smoke of a burning mixture composed in part of the powdered cinders of a meteorite in the belief that the effect on the child would be to invigorate his mind and engender courage in his disposition. Some writers believe that the sacred "black rock" of Mecca is a stony meteorite,[34,35,47,87,91,118] and that its fall may be associated with the vision that stimulated Mohammed to preach his new theology.[69] There is an interesting legend associated with the three large North Greenland (Cape York) iron meteorites whose existence had been surmised for many years prior to their discovery by Peary in 1894.[85] (A fourth large meteorite belonging to this group was discovered by Rasmussen in 1913[12a]). The large masses were believed by the Eskimos to have originally been a woman and her dog and tent hurled from the sky (presumably because of some misdemeanour[69]) by the Evil Spirit.[85]

It has been known since the visit of Sir John Ross to Greenland in 1818[92] (and perhaps for a longer time[91]) that the Eskimos made use of meteorites;* chippings of the latter were fashioned into

*The iron brought from Greenland by Sir John Ross was identified as meteoritic by a "Dr. Wollaston." This was undoubtedly William Wollaston (1766-1828), the eminent British scientist who discovered and named the

harpoon points, knives, and rough cutting tools.[64,69,85,113] Other peoples who have employed meteoritic iron for the production of tools, weapons or ornaments include the Mayas of Yucatán, the Incas of Peru, and the Aztecs of Mexico,[48] the South[118] and North[64] American Indians, and the mound-builders of Ohio.[88] It has been noted[91,118] that because of the nickel content of meteoritic iron, primitive man had the use of a natural alloy* superior to any metal smelted for manufacture previous to the introduction of nickel-steel** in the late nineteenth century. Because of the heavenly origin of meteorites they were often looked upon with veneration or fear, as mentioned above, rather than as a possible raw material for the making of implements; and to peoples unacquainted with the manufacture of iron by the reduction of ores, the scarcity of this metal has led to meteoritic iron being prized more highly than gold.[90,91]

Introduction

Possibly the oldest meteorite preserved as such is one that fell in 1492 at Ensisheim in Alsace. Since that time meteorites from over one thousand distinct falls have been recoverd.[37,47,113] It is said that in the present decade approximately twenty-five new meteorites are being reported each year; many of these are found in the United States by members of the Meteoritical Society (until very recently known as the Society for Research on Meteorites). These newly-recorded finds include many recognitions of old meteorites.

It has been estimated[29,64,69,113] that perhaps fifteen million to ten billion meteors enter the earth's atmosphere each day where they are heated to incandesence by friction with the air and give, if sufficiently large, the effect of 'shooting stars' or, in exceptional cases, fireballs. F. G. Watson of the Harvard Observatory has calculated[113] that a meteor with a visual magnitude of 10 will have a mass of 2.5×10^{-5} grams and that one with a magnitude of -3 will have a mass of only 4 grams. Estimates of the mass of the average meteor

elements palladium and rhodium, and who developed the reflecting goniometer, microscope lens systems, methods of working platinum, etc.

*Since writing this paper, the author has had his attention drawn to the excellent work on "The Use of Meteoric Iron" by Dr. T. A. Rickard, *J. Royal Anthropological Inst.*, vol. 71, p. 55, 1941. In this paper there are given a number of additional examples of the uses to which meteorites have been put in ancient and modern times, and also other interesting data about meteorites.

**Which, interestingly enough, was at first called "meteor steel."

(not meteorite) vary from 80 milligrams[109] to several pounds.[69] Only a very minute proportion of the meteors,* perhaps only those brighter than magnitude —10, reach the earth as discrete meteorites. For a meteor to retain its identity after passing through the atmosphere, it must enter the latter with a considerable mass; the calculated figures are from 5 to 20 pounds.[64,113,115]

The weight of the earth's total accretion of meteoritic material (including meteoritic dust) has been variously estimated from about one ton [109,113] to fifty thousand tons[69] per day. It has been calculated[64] that an annual increment of ninety-three thousand tons, if spread out evenly and continued for a period of three hundred and fifty million years, would form a layer one inch in thickness over the entire surface of the earth. According to Young,[117] the accumulation of meteoritic matter by the earth theoretically should shorten the year in three distinct ways. The total effect, assuming a daily accretion of one hundred tons of ultra-terrestrial matter, does not amount to a thousandth of a second in a million years.

There is wide disagreement regarding the number of meteorites, of a size permitting recognition as such, falling on the surface of the earth. For example, figures have been given ranging, on an annual basis, from ten or twenty for the entire earth to two hundred and fifty for the United States.[29,50,89,113] Although animals have been struck by meteorites, there appears to be on record no authentic case[50,64,113] (or perhaps one[35]) of a human being having been killed by this agency. (Stratosphere flying may lead to accidents as a result of collision with an unconsumed meteor of appreciable size!)

Matter recognizable as meteoritic is of many different varieties (perhaps seventy or eighty[72]), and several detailed classifications of meteorites have been proposed (e.g.,[27,34,58,64,87]). Three inter-related main types** may be differentiated. These are the irons (or siderites) which are composed almost wholly of iron alloyed with nickel and with very little or no siliceous material, the stones (or aerolites) which consist largely of very basic silicate minerals and contain very little, or occasionally no metallic matter, and an intermediate type (the stony-irons or siderolites) which contain appreciable quantities

*Watson[113] considers that there can be no meteors fainter than the 30th magnitude, since particles producing less light than this would be sufficiently small to be blown away from the solar system by the sun's radiation pressure.

**Excluding the glass-like tektites which may be extra-terrestrial in origin.[84,113]

of both metallic and stony matter. These three types may each be divided into several sub-groups.[22]

It is very difficult to assess the relative proportion in which the main classes of meteorites reach the earth. The irons constitute over 90 per cent. of the total weight of meteorites[22] (both those seen to fall and immediately recovered and those accidently found and subsequently recognized as meteorites). But it must be borne in mind that the irons are much more readily recognized as bodies of non-terrestrial origin than are the stones. Since terrestrial iron is a rarity,[82] a mass of this metal on the earth's surface is so unusual that even an unskilled observer is likely to recognize it as extraordinary, but stony meteorites are readily overlooked because they often resemble common stones in external appearance. Among the witnessed falls, stony meteorites are very much more common[113] than the iron or siderite type. Some authorities believe that both the weight[50,112] and the number[37,64,113] of stones falling on the earth are greater than those of the siderites.

As is well known, masses recognizable as meteorites when found on the earth vary in weight from a fraction of an ounce to many tons; the average is estimated variously from two ounces[69] to forty-four pounds.[113] A few examples of large or even gigantic meteoritic falls may be mentioned. A crater near Winslow, Arizona, discovered in 1891, is about four thousand feet in diameter and six hundred feet deep, with the rim of the crater one hundred and twenty feet or more above the surrounding plain. In the vicinity of this crater, some ten to twenty tons of meteoritic material (in thousands of fragments) have been found on the surface and metallic masses, perhaps part of the main body, have been located by drilling operations. The Siberian fall of June 30, 1908, which occurred in an isolated region some four hundred miles north-east of Lake Baikal, produced a column of fire visible from three hundred miles. This fall caused widespread devastation out to a distance of some twenty to thirty miles from the craters (of which there are at least ten of a size thirty to one hundred and sixty feet across), as evidenced by the fact that the trees were blown over to lie along lines radiating from the craters (figure 1). Effects of the blasts of hot air which shot out when the meteorites struck the earth were apparent at distances up to forty and fifty-five miles from the craters. In all, many hundred square miles of territory were affected by this fall, the weight of

which has been assessed as high as forty thousand tons (this estimate is probably too high[3,56]). The resultant air-wave reached England, thirty-four hundred miles away, some five hours after the impact, and European seismographs recorded a strong ground wave. Other important meteoritic craters have been recognized in central Australia, in Arabia, in Estonia, and elsewhere.

Meteoritic crater formation is probably due more to an explosive reaction than to a percussion action.[100] When a huge mass hits the ground, its motion is checked in a fraction of a second, and the intense heat resulting from the compression of both the meteorite and the surrounding terrain vaporizes much material, including ground water. This expanding gas gives rise to an explosion which digs out the crater, shatters much of the meteorite,* and distributes it widely over the surrounding area.

The largest meteorite that has been recovered, or at least partially excavated, is the Hoba West metallic meteorite which weighs perhaps sixty to one hundred tons and lies where it was found near Grootfontein in South West Africa. A meteorite estimated to weigh thirty-three to thirty-seven tons was removed from the vicinity of Cape York, Greenland, by Peary in 1897, and is on exhibition in New York City. Several meteorites weighing more than a ton each are preserved in various museums.[34]

These huge meteorites are all of the siderite type. Although this class of meteorite may sometimes fall in several pieces, in general siderites probably do not shatter during their fall through the atmosphere. On the other hand, it is likely that the majority of stony meteorites, due to their nature, become broken into smaller fragments during their fall to earth.** Thus no stony meteorites whose weights are measured by tons have ever been found; the largest stony meteorite recovered in one piece weighs less than eight hundred pounds.[50,113] Stony meteorites may enter the atmosphere, and certainly arrive on the earth, in clusters of tremendous size, e.g., a fall in 1868 at Pultusk, Poland, is reported to have been composed of as many as one hundred thousand meteorites, and other falls comprised of many thousands of single individuals are known.

*The heat energy (perhaps 450,000 calories per gram) generated by the impact of a gigantic mass may be sufficient to vaporize the meteorite.[12,62]

**From the interesting and exciting fall of stony meteorites near Chatham, Ontario, in July 1939, the largest single fragment recovered weighed eighty-eight pounds.[104]

Some Physical Properties of Siderites

In addition to occurring in the wide range of sizes to which reference has been made, siderite meteorites exhibit a variety of shapes.[34] For example, some approach the shape of a cone, or a shield, or a pear; others are annular, and many are irregular in outline.[82] The surface of a fresh specimen is coated to a depth of up to about 2 mm. with a fused layer of magnetite[82,86] and/or other dark oxides;[34] this crust is the result of oxidation of the metal during its passage at high temperature through the earth's atmosphere.

Rust-brown or yellowish coloured spots on meteorites are normally caused by the oxidation, under the moist conditions so common on the earth's surface, of one or more of the constituents of the meteorite. The metal of siderites, before oxidation or weathering has occurred, is grey or silver-white.[34] Meteoritic iron is magnetic[34,82] and usually malleable.[64,118] The density of a siderite meteorite usually is within the range 7.0 to 8.1;[22] the average density is close to 7.7.[82]

Some siderites have maintained an almost uniform orientation during their fall through the atmosphere;[71] in such cases the head side may be smooth or covered with elongated or radial grooves which indicate the direction of flight. Frequently the surface is pitted with depressions which may be shallow or deep, and are often circular or oval-shaped giving the effect of thumb markings or piezoglyphs[64] (figure 2). These latter are due, in part at least, to the unequal resistance of the various portions of the unhomogeneous meteorite to the attack of the hot air close to it during the fall through the atmosphere.

It is probable that most siderite meteorites, excluding the gigantic ones, are no more than slightly too hot to handle, when they first land on the surface of the earth.[64,113] It is possible, however, that some records of encounters with extremely hot iron meteorites are authentic.[50,69]

Chemical Analysis of Siderites

To refer to siderite meteorites as 'irons', or even to consider them as masses composed only of iron-nickel alloys, is an over-simplification. It is true that the iron and nickel normally account for approximately 99 per cent. of the mass of a siderite, and that there are only

a few other elements occurring commonly in concentrations greater than 0.05 per cent., but nevertheless the presence of over seventy elements has been established. With improved methods of analysis, and the development of new techniques for the detection and estimation of elements in trace quantities, it is highly probable that most or all of those elements yet undetected in siderites will in time be shown to be present. In fact, if one considers meteorites in general and not the siderite type alone, it is found that all but seven* of the elements known to occur terrestrially have been detected in one meteorite or another.

Before the analysis of a meteorite is undertaken, the oxidized surface crust should be removed. It is worth pointing out that even a careful chemical analysis of a meteorite will not normally give an accurate picture of its composition. This is so because the elements that occur are not distributed uniformly throughout the mass of the material—a meteorite does not possess a chemically homogeneous structure. Representative sampling, except by accident, can be carried out only by a method involving the destruction of the entire meteorite; manifestly, such a technique is rarely used. Nevertheless, the combination of results from a very large number of analyses carried out using different siderites, even if each individual analysis is in error by virtue of improper sampling, no doubt yields figures that closely represent the average chemical composition. The latter, for siderite meteorites, is probably not far removed from the following values:**

Fe	90.45%	Cr	0.03
Ni	8.55	P	0.18
Co	0.61	S	0.08
Cu	0.04	C	0.06

*These are the inert gases neon, krypton, xenon, and the radioactive elements polonium, actinium, astatine (element 85), and francium (element 87). The natural occurrence, terrestrial or otherwise, of element 61 and of technetium (element 43) has not yet been proven,[84a] although radioactive isotopes of both these elements have been identified among the fission products of uranium (J. Am. Chem. Soc. vol. 68, p. 2411, 1946), and technetium has been formed by the neutron or deuteron bombardment of molybdenum in a cyclotron.[85a] The newly-discovered transuranic elements, neptunium, plutonium, americium, and curium (elements 93-96), have not yet been found in nature with the exception of plutonium,[97] (which apparently occurs in the ores pitchblende and carnotite[97a] to the extent of about one part in 10^{14}).

**Compiled from the work of Farrington,[32,33] Tschirwinsky,[27] and Noddack.[76]

Individual meteorites may, of course, show considerable variation from these average percentages. Furthermore, the above tabulation takes account of only a very few of the elements known to occur in siderite meteorites.

From a rather extensive (although not exhaustive) survey of the chemical literature of the last twenty-five years, the following tabulation has been made of the highest concentrations in which elements have been reported to occur in siderite meteorites. The values found, expressed as orders of magnitude, in weight percentage, follow:

10^{1}	10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-10}
Fe	Co	Al	As	Ga	Ag	Bi	Ce	He	Ra
Ni	P	C	Ga	H	Au	Sc	Dy	Re	
	S	Cl	Ir	Mo	Br	Y	Er		
		Cr	Mg	N	Cd		Gd		
		Cu	Mn	Pd	I		La		
		Ge	Pt	Pb	Os		Nd		
		Si	Ru		Rh		Pr		
		Ti	Sn		Se		Sm		
			Zn		Sb		Th		
					Ta		Yb		
					V		U		
					W				
					Zr				

A number of other elements have been found in siderites by X-ray, spectroscopic, or other techniques. These include: B, Ba, Be, Cs, Hf, Hg, In, K, Li, Na, O, Sr, Te, and Tl.

Because the orders of magnitude given in the above table refer to the highest values located, they are in many cases far above the concentrations at which the elements normally occur. For example, phosphorus is rarely present at a concentration above 1 per cent. and perhaps not often above 0.5 per cent., most determinations of radium in siderites show this element present at a concentration of the order of 10^{-12} per cent. rather than 10^{-10} per cent., and platinum occurs more commonly at a concentration of the order of 10^{-3} per cent. or 10^{-4} per cent. than one of 10^{-2} per cent. A high concentration of the platinum metals is usually found associated with a correspondingly high nickel content.[45]

It is of interest to compare the isotopic constitution of an element obtained from meteoritic matter with the composition of the same element from terrestrial material. Such a comparison may be carried out, indirectly (for example) by means of atomic weight determina-

tions, and directly by the use of a mass spectrometer. Such studies have been made in the cases of iron,[7,11,106] nickel,[6,8,9] cobalt,[5] carbon,[66,68] chlorine,[43] silicon,[52] and oxygen[59] (the meteoritic material for at least the first four elements named was from a siderite meteorite). In no instance was any evidence obtained to indicate that meteoritic matter has an isotopic constitution different from terrestrial matter (provided that meteoritic carbon was compared with terrestrial carbon of igneous origin). Now the isotopic abundance ratio of terrestrial carbon (C^{12}/C^{13}) varies slightly with the source of the carbon;[66] the natural abundance of the isotopes of certain, at least, of the other elements (hydrogen,[105] oxygen,[28] nitrogen[94]) likewise varies slightly on earth—these variations are due to a fractionation process in nature. We may expect that refinements in technique will disclose slight differences in the isotopic composition of meteoritic and terrestrial elements. If these differences are not relatively great—and they are most unlikely to be because no differences at all have as yet been found—then the evidence of these isotopic studies lends some support to the view that meteorites and the earth have a common origin. Identical or even very similar isotopic mixtures would not likely be generated entirely independently because "we have reasons to believe that the atom-building processes depend on the temperature and history of the star in which they take place"[84] (cf., however,[3]).

In investigations[95,96] using stony meteorites from the Pultusk fall in comparison with terrestrial material, it has been shown that there is no detectable difference in the proportion of $_{19}K^{40}$ (a radioactive isotope of potassium) present in the two cases, nor in the $_{92}U^{235}/_{92}U^{238}$ ratios for the two types of matter. The isotopic composition of a radioactive element varies with the age of the element, and hence the agreement found in these cases (and others[103]) would suggest that meteoritic and terrestrial matter are the same age.

The thorium and uranium occurring in a siderite give rise, by processes of radioactive disintegration, to helium which is retained in the meteorite as occluded gas. If the concentrations of these three elements in a siderite are determined, the time elapsed since the final solidification of the meteorite may be calculated (assuming that all the helium has originated from uranium and thorium) by making use of the well-established laws governing the radioactive decay of these latter two elements. Some years ago, F. A. Paneth and some of his associates[83] measured the helium and uranium content of some thirty

siderites, and the ages of the latter calculated from these data extended to twenty-eight hundred million years. More recently, after they had developed a method for the determination of the thorium content of iron meteorites, Paneth and his co-workers analyzed six siderites for thorium, uranium, and helium, and from these determinations calculated the ages (since solidification) of the meteorites to range up to approximately seven billion years.[2] It may be noted in passing that it has been stated recently[18] that "the geochemical evidence bearing on the age of the earth and meteorites, the galactic star clusters, the statistics of binary stars, the clusters of extra-galactic nebulae and finally the system of the nebulae, all agree in pointing to a time scale of the order of a few billion years. It does not seem that this can be accidental."

The most recent work[2] on the ages of meteorites indicates that times varying from less than one hundred million to about seven thousand million years have elapsed since final solidification of the meteorites studied. A number of proposals have been made in attempts to account for this very large spread. It has been suggested that low helium contents (which would lead to calculated 'youthful' ages) may have been caused by loss of helium resulting from the meteorite becoming molten by one or more comparatively close perihelion passages.[51,84] A comparison[22] of the measured and calculated (from a knowledge of the constituent metallic alloys) specific gravities of a number of siderites would suggest that the latter are porous (to the extent of perhaps 2.6 per cent. of the bulk volume) possibly by virtue of the presence of minute fissures; the latter may have allowed leakage of helium from the meteorite. Another possible explanation of the differences in time elapsed since solidification is that meteorites may have originated from a planetoid which, until its disruption at a comparatively recent date, retained a core part solid and part liquid.[113]

It is of importance to enquire whether the elements present in siderites occur in the free or combined state, and if the latter, to investigate the nature of the compound or compounds present. Information regarding these matters* is available at present only for a comparatively few of the elements, in general for those occurring in

*In the remainder of this section of the paper, much of the data to which reference is not specifically made is drawn from the work of Farrington,[34] Merrill,[65] and Palache et al.[82]

relatively high concentration. Many of the elements present in siderites occur in more than one state of combination.

Siderites may contain at least eight minerals that have iron as a major constituent. These are: kamacite and taenite (alloys composed largely of iron and nickel), schreibersite (an iron-nickel phosphide), cohenite (an iron-nickel carbide), lawrencite (mainly ferrous chloride), daubréelite (ferrous-chromium sulfide), chromite (mainly ferrous chromate), and troilite (ferrous sulfide). Nickel is an important constituent of several of these, and small amounts of cobalt are usually associated with the four minerals first named.

Kamacite* and taenite,** which usually occur in the form of thin plates, consist principally of metallic iron and nickel. Analyses of the nickel content of kamacite give fairly consistent results (5-7 per cent.); the nickel percentage of taenite has been reported as low as 13 per cent.[107] and as high as 55 per cent.;[99] but is commonly in the range 24-37 per cent. The nature of these two alloys and the interrelationships which exist between them will be briefly discussed later in the paper. Both are solid solutions of nickel and iron together with accessory elements (usually there are present fractional percentages of cobalt and carbon, and perhaps of copper; platinum and many or all of the platinum metals—osmium, iridium, ruthenium, rhodium, and palladium—are normally present in very small proportions, probably alloyed with the iron-nickel). Plessite,† very often present in siderites, is generally considered to be an intimate eutectic mixture of kamacite and taenite, although other explanations[13,80,99] of its nature have been advanced.

Schreibersite,‡ which probably is present in all siderites, normally occurs in plate-like structures as oriented inclusions in the kamacite, troilite, or graphite of the meteorite. When this phosphide occurs in acicular condition rather than with a platy habit, it is usually called rhabdite†† (cf., however, [86]). Analyses of different samples of schreibersite differ slightly with respect to the concentrations of the major constituents found, e.g., iron, from less than 50 to about 70 per cent.; nickel from about 10 to 35 per cent.; phosphorus, 13 to 16 per

*From κάμαξ, a pole, stake or shaft (from the appearance on etching). Information regarding the source of the name of this and other minerals referred to below is taken from Palache,[82] Farrington,[31] and Bailey.[4]

**From ταινία, a ribbon or band.

†Possibly from πλήσω, I shall fill.

‡After Director Karl Fr. A. von Schreibers (1775-1852) of Vienna.

††From ῥάβδος, a rod, wand, or stick.

cent.; and fractional percentages of cobalt and copper. There is some evidence[16] that the formula for schreibersite is Fe_2NiP, but the variety of analyses reported, if reliable, would suggest that this mineral exhibits solid solution phenomena.

Cohenite* has been considered as the iron-nickel carbide $(Fe,Ni)_3C$, but the analytical results are variable (iron, 83-92 per cent.; nickel, 2-10 per cent.; carbon, 5-7 per cent.; and usually cobalt, less than 2 per cent.). It occurs in comparatively few meteorites, usually in the form of elongated tabular crystals.

Lawrencite,** which is mainly ferrous chloride though perhaps containing some nickel, is (as a result of its oxidation) one of the principal causes of the development of yellow and/or brown stains on meteorites that have not been protected against oxidizing and weathering agencies.

The few published analyses of daubréelite† indicate that its composition is close to that demanded by the formula Cr_2FeS_4 (FeS, Cr_2S_3). This mineral occurs in meteorites bordering nodules of troilite, or crossing them in veins, or as thin plates or grains.

Chromite, which is ferrous chromate with variable amounts of aluminium (replacing chromium) and magnesium (substituting for the iron), is not an infrequent constituent in siderite meteorites, although the amount present is normally comparatively small. It commonly occurs in siderites in the form of nodules.

The composition of troilite‡ usually approximates that of ferrous sulfide, but with some nickel, and perhaps cobalt and copper, present. Troilite is an almost universal constituent of siderites. It occurs as irregular masses and in plate-like forms, but usually as distinct nodules. The irregular surface effects exhibited by siderites are thought caused, in part at least, by the burning out of troilite inclusions during the flight of the iron through the earth's atmosphere (figure 4). Inclusions of troilite, and also those of schreibersite and cohenite, are sometimes surrounded by narrow bands of kamacite; or occurrences of troilite may be bordered by a thin layer of schreibersite or daubréelite. Other zonal arrangements are known—for ex-

*After Dr. E. Cohen (1842-1905), Professor of Mineralogy at Greifswald.

**Named by Daubrée in honour of J. Lawrence Smith, the analytical chemist who identified it.

†Discovered by Smith and named in honour of Prof. G. A. Daubrée (1814-1896) of Paris, who worked extensively with meteorites.

‡Named in honour of Dominico Troili, a Jesuit priest, who in 1766 mentioned an iron sulfide found in a meteorite.

ample, troilite may be bounded by a layer of graphite, and that by one of schreibersite or cohenite, or troilite may be surrounded by schreibersite and that in turn by kamacite.

Carbon, in addition to being present in siderites as a major constituent of cohenite, and as a minor constituent in kamacite and taenite, occurs in siderites in other forms. It has been found as a silicon carbide called moissanite,* and occurs in the elemental form commonly as spherical masses of amorphous carbon (often surrounded by a halo of schreibersite), as lamillae or more often nodules of graphite, occasionally as cliftonite** (a cubic form of carbon with a hardness approximating that of graphite) and uncommonly in the form of microscopically minute diamonds.[34,57,73]

Carbon as carbon monoxide, carbon dioxide, and methane may be present as occluded gas. Other gases that occur are hydrogen, nitrogen, and, as mentioned earlier, helium. Hydrogen and carbon monoxide are reported[22,34,65,87,113] to constitute a large proportion of the total volume of gas occluded in siderites.

Silicon, as noted above, sometimes occurs in siderites as moissanite; in low concentration it may, on occasion, be present in the form of silicate minerals such as olivine and anorthite which also contain oxygen, aluminium, and akali and alkaline earth metals. Gold has been reported to occur native in siderites in the form of minute grains. At least one instance of the occurrence of native copper in an iron meteorite has been recorded.[15]

Little information is as yet available regarding the state of combination of the other elements demonstrated to be present in siderites. Iron-nickel alloys account for a very high proportion of the mass of a siderite meteorite; other substances such as phosphide, carbide, sulfides, carbon, etc., are important inclusions, although small and variable in quantity.

The physical and chemical properties, cleavages, and structure of the unit cell of many of the siderite minerals have been studied and described.[34,82,86] It is interesting to note that of the minerals mentioned all have been recognized in terrestrial rocks except schreibersite, daubréelite, moissanite, and cliftonite.

---

*After Prof. Henri Moissan (1852-1907) who discovered the natural occurrence.

**After R. B. Clifton, Professor of Physics at Oxford, though not the discoverer of the mineral.

(*To be Concluded*)

THE MARTIAN MERRY-GO-ROUND

By D. W. Rosebrugh

LIKE most amateur observers the writer has neither the spare time nor the equipment to make a serious study of Mars. Quite by accident Mr. Herbert M. Harris, Secretary, A.A.V.S.O., South Portland, Maine, and the writer evolved a technique of competitive co-operative observing at the 1946 opposition which increased both their knowledge of Martian topography and their pleasure in observing Mars manyfold. Perhaps other pairs of observers equipped with 4 to 6-inch refractors or 6 to 8-inch reflectors may similarly find their enjoyment of Mars enhanced by following this technique at future more favourable oppositions.

On January 21, 1946, Mr. Harris sent the writer a sketch of Mars as he saw it at 8.30 p.m. E.S.T. This showed Syrtis Major and the North Polar Cap very clearly. This letter was crossed in the mail by a card which the writer sent Mr. Harris showing Syrtis Major, Boreosyrtis and Aeris as they appeared on January 23 at 9.30.

As a result of this spontaneous interchange of sketches it was agreed to follow Mars for about forty days, in an attempt to identify the major features on its entire disc and to interchange sketches as a confirmation and encouragement to the other observer. No attempt was made to do any work of scientific value. The observers merely looked at Mars when convenient and enjoyed it as a natural spectacle and made simple pencil sketches later by memory of what they had seen. After sketching his impressions of the planet each observer compared his drawing with the map of Mars by Antoniadi shown on page 7 of the April 1942 issue of *Sky & Telescope* and identified what he had seen.

Experience, or rather inexperience, indicated that it is very hard to reconcile what one sees on the globe of Mars, with a flat Mercator projection map, so ping-pong balls were secured on which were inked in latitude and longitude lines and a few of the major details of Mars. When lacquered these ceased to smudge and by referring to them and to the map by Antoniadi it was possible to identify most of the details shown on the sketches made.

The rotation period of Mars is 24 hours, 37 minutes, 22.58 seconds or 1.025,955,787 days. Hence Mars fails to make a complete rota-

tion in 24 hours by about 9 degrees of its own longitude. Therefore 40 nights after the beginning of the program it was to be expected that Syrtis Major, longitude 290 degrees would again appear central on Mars' disc. In the meantime, however, by observing say once every 5 days, the planet would present centrally to view longitude 245, longitude 200, longitude 155 and so on until after 8 such periods longitude 290 degrees and Syrtis Major would again appear in view. Sure enough on February 28 at 7.30 to 8.00 p.m. Syrtis Major was again seen by both observers. It appeared at a little to the left of centre (in the celestial telescope) but by March 3 at 7.30 it had returned to about the same central location it occupied on January 23, nearly forty days before.

As an instance of how the two observers confirmed each other's observations one might take the post card of January 27, 8.15 p.m., which Mr. Harris sent the writer and that of January 29, 8.30 p.m., which the writer sent Mr. Harris. Mr. Harris' sketch with the longitude 230 central on the disc showed the North Polar Cap, Utopia, Eunostos, Cyclops, Thoth, Maria Cimmerium, Sirenum and Chronium and the light areas Aeolis, Isidis R., Aethiopis and Memnonia. The writer's sketch showed longitude 210 on the meridian. The North Polar Cap, Phlegra, Cyclops, Maria Cimmerium, Sirenum and Chronium and the lighter areas Aetheris, Isidis R., Elysium, Aethiopis and Aeolis can be identified with reasonable certainty but the whole Martian terrain was shifted nearly 20 Martian degrees of longitude to the right (in the telescope) because the sketch was made two days later.

Twelve details were seen by both observers, most of them several times, and 11 other details were seen by one or the other observer twice or more. Twenty-two other details appear once in the sketches made. Thoth, Ganges, Nilokeras and Ceraunius were seen. It may be that these are classified as canals but to the observers they appeared merely as elongated smudges. The beginnings of Canal Gehon were seen, but not its slenderest portion, which both Mr. Harris and the writer saw in December 1943. At that time the writer was using an 8¾-inch reflector of 73½ inches focal length diaphragmed down to 5¼-inch aperture. Nilosyrtis, the largest of the canals was discerned but not its entire length.

Mr. Harris used his 6-inch Clark refractor with a 200-power orthoscopic eyepiece for this work. This is mounted on a pier with

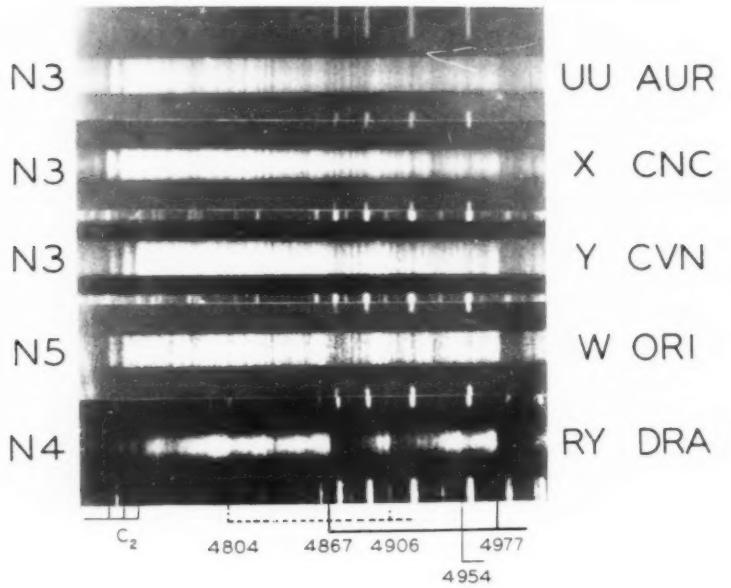
motor drive in his sliding roof observatory. The writer used his 6.2-inch refractor with a 186-power eyepiece, both made by the late Mr. Elroy Gray, amateur observer of North Jay, Maine, on a portable mount with hand slow motion in right ascension. A higher power might have been desirable to reduce the glare of the planet, but this would have introduced too much unsteadiness, so, especially as the planet grew smaller as it receded, it was found that a yellow camera filter snapped over the eyepiece clarified the view.

The writer has been asked by many amateur observers as to the relative qualities of refractors and reflectors. The writer is no expert on this matter but his impressions are that his 8¾-inch Mellish reflector, which has an excellent figure and diagonal flat, tests better than it performs. In, say, 1000 seconds at the eyepiece of a refractor, good clear views of Mars are obtained for perhaps 250 seconds. In 1000 seconds with the writer's reflector a good clear view of Mars is obtained only for perhaps one second. This view, however, is better than the writer has ever obtained with either his former 6-inch Clark refractor or his present 6.2-inch amateur made refractor. The fact that an exceptionally clear view is obtained intermittently with the reflector testifies to its optical excellence, but the fact that such views can be obtained only about 1/10% of the time is due to the susceptibility of reflectors to changes in temperature and atmospheric irregularities, especially in the tube itself.

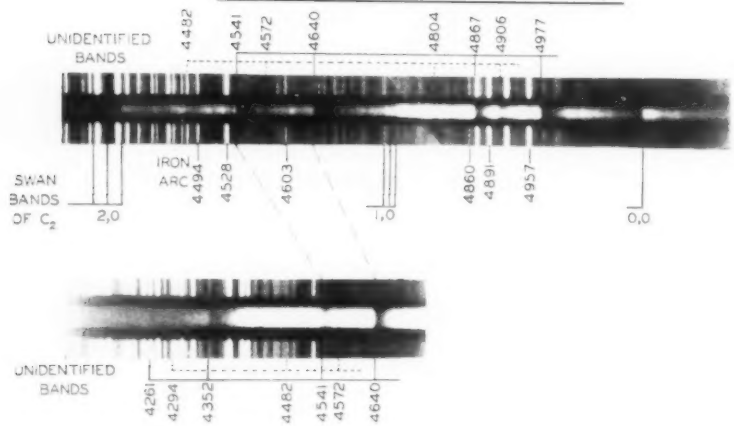
87 Fern Circle,
Waterbury, Connecticut.

PLATE V

UNIDENTIFIED BLUE-GREEN BANDS



RY DRACONIS N4 ($C4_4$)



THE UNIDENTIFIED BLUE-GREEN BANDS IN CERTAIN N-TYPE STELLAR SPECTRA*

By ANDREW MCKELLAR

(With Plate V)

ABSTRACT

The unidentified red-degraded absorption bands occurring in the blue-green region of a number of N-type stellar spectra studied earlier by Merrill, by Sanford and by Shane, have been measured on fourteen spectrograms of RY Draconis where the bands occur with great strength. These measurements were supplemented by others on eight plates of five additional stars where the bands are weaker. Two new strong bands further to the violet ($\lambda\lambda$4352 and 4261) and three weaker ones have been added to the six heretofore known. The possibility of a band head at λ4954 in the spectrum of RY Draconis being due to TiO is pointed out.

From studies of the unidentified bands it is concluded that the strong bands are probably the 0,0, 1,0 and 2,0 transitions of a doublet system and the weaker bands the same transitions of another doublet system due to the same molecule. Analyses of the systems yield vibrational frequencies of some 1500 cm.$^{-1}$ and doublet splittings of about 450 cm.$^{-1}$. It is therefore suggested that the molecule responsible for the bands has at least one atom not heavier than those in the first row of the periodic table and that it is possibly a hydride of an element in about the fourth row of the table. Likely molecules include TiH and FeH, the spectra of which have not yet been produced in the laboratory. The arguments for these two possible identifications are briefly presented.

In 1926 attention was directed by Merrill[1] to a definite absorption band λ4976 in the spectrum of UV Aurigae and by Sanford[2] to the same band as well as to others in the region λ4800 to λ5000 in the spectra of a number of stars of type N. The new bands were unlike bands of the Swan system of C_2 which characterise N-type spectra in that they were degraded to the red. The three strongest band heads were measured by Sanford at $\lambda\lambda$4868, 4905 and 4979. These bands did not correspond to any that had been produced in the laboratory.

---

*Contributions from the Dominion Astrophysical Observatory, No. 7.

[1]*P.A.S.P.* vol. 38, p. 175, 1926.

[2]*P.A.S.P.* vol. 38, p. 177, 1926.

In 1928 Shane,[3] in the course of a study of N-type stellar spectra, found three additional bands in the λ4540 to λ4640 region similar in character to the three strongest referred to above. The wave-lengths and descriptions of the six bands according to Shane were:

Group 1	*Group 2*	
λ4642	λ4976	—Wide, strongly degraded toward red
4572	4905	—Narrow
4540	4866	—Moderate width, slightly degraded toward red

Shane remarked "An examination of the plates at once suggests that these six bands fall into two very similar groups. In the two groups the separations of corresponding bands are nearly the same. Furthermore, the relative intensities within each group appear to remain constant. These facts strongly suggest a common origin for the six bands." The identity of the absorbing molecule remained unknown.

In 1937 Wurm[4] suggested that the two strongest bands, λλ4976 and 4642, were due to heads formed by the convergence of bands of the 0,0 (λ5165) and 1,0 (λ4737) sequences of the Swan system of C_2. However, (1) the Swan bands are relatively weak in certain spectra in which the unidentified bands are strongest, (2) the calculated convergence limits of the two C_2 sequences are about 10 Angstrom units from the observed band heads, and (3) the two bands in question are obviously related to the others left unidentified, as will be emphasized later, so Wurm's suggested identification must almost certainly be considered untenable.

The writer's interest in the unidentified bands was aroused when, during a study of the isotope effect in the Swan bands, a spectrogram of the N-type star RY Draconis showed the presence of the blue-green bands in great strength. The present paper was prepared (1) to report on some further new bands of the system which have been found, (2) to give improved wave-lengths for the band heads, (3) to extend Shane's conclusions regarding the regularities of the band-head positions (essentially to give a vibrational analysis) and to examine the clues thereby given as to the nature of the absorbing molecule, and (4) to re-direct attention to the bands in the hope that spectroscopists might undertake investigations leading to their production in the laboratory.

[3] *Lick O.B.* vol. 13, p. 123, 1928.
[4] *Z.f.Ap.*, vol. 13, p. 179, 1937.

Observational Material and Measurements

Measurements were made on fourteen spectrograms of RY Draconis covering various regions between λ4200 and λ5200. Twelve of the plates were obtained with the IM, IS, ISS, and two-prism ultra-violet, spectrographs at Victoria (dispersions from 30 to 135 A./mm. at Hγ). The other two had been obtained for the writer by the late Dr. A. B. Wyse, of the Lick Observatory, using a very fast nebular spectrograph of low dispersion (about 450 A./mm. at Hγ).

The mean wave-lengths of the main spectral features are given in Table I. The unidentified groups of band heads are indicated, the strong heads by one asterisk and the weaker ones by two. Nearly all the remaining narrow absorption features are, as yet, unidentified. Most of them, especially those to the red of λ4867, are undoubtedly structural details of the unidentified band system or systems. A few of the features correspond in wave-length to lines measured by Hale, Ellerman and Parkhurst[5] in the spectra of all eight of the stars studied in their early investigation of the carbon stars.

In addition to the plates of RY Draconis, one or more of the unidentified bands were measured on three plates of V Coronae Borealis, and one plate each of RV Cygni, U Camelopardalis, W Orionis, X Cancri and UU Aurigae. For the first three of these stars, the bands occur with considerable strength.

The average wave-lengths and corresponding wave-numbers of the heads of the unidentified bands, for all the stars, as measured by the writer, are shown in Table II. (The values indicated on Plate V are these mean wave-lengths to the nearest Angsstrom unit). In obtaining the average, weights were assigned according to the number of spectrograms measured.

Plate V showing the λ4730 to λ5000 region in the spectra of five cool carbon stars illustrates the variation in strength of the unidentified bands. The growth in intensity from UU Aurigae to RY Draconis is shown best by the λ4977 band. The spectral types in which the unidentified bands are noted cover the range from N2 to N6 or from C4 to C7 on Keenan and Morgan's system.[6] From an

[5] *P. Yerkes O.*, vol. 2, p. 253, 1903 (Table on p. 363).
[6] *Ap. J.*, vol. 94, p. 501, 1941.

TABLE I

MEASUREMENTS OF SPECTROGRAMS OF RY DRACONIS

Spectral Feature	Number of Plates on which measured	Wave-length	Identification	Laboratory Wave-length
Band head degraded to violet	1	4216	0,1 violet CN band	4216.0
Strong absorption feature	2	27	Ultimate line of Ca I	4226.73
Head of strong band degraded to red	3	61*		
Narrow absorption feature, moderately strong, violet edge	2	94**		
Narrow absorption feature, moderately strong, centre	2	99		
Head of band degraded to violet	2	4314	λ4315 band of CH	4315.0
Head of strong band degraded to red	4	52*		
Head of band degraded to violet	3	83.9	2,0 band of C_2 Swan System, $C^{12}C^{12}$	4382.5
Head of band degraded to violet	3	95.8	2,0 band of C_2 Swan System, $C^{12}C^{13}$	4395.3
Head of band degraded to violet	3	4409.5	2,0 band of C_2 Swan System, $C^{13}C^{13}$	4408.5
Head of possible weak band degraded to red.	2	82**		
Centre of this band	1	85		
Centre of absorption feature	1	95		
Centre of absorption feature	1	4514		
Centre of absorption feature	2	33		
Head of strong band degraded to red	3	42*		
Head of weak band degraded to red	2	72**		
Head of very strong band degraded to red	3	4640.5*		
Redward end of very deep portion of this band	1	65		

TABLE I—(*continued*)

Spectral Feature	Number of Plates on which measured	Wave-length	Identification	Laboratory Wave-length
Head of strong band degraded to violet....	4	4737.5	1,0 band of C_2 Swan System $C^{12}C^{12}$	4737.1
Head of strong band degraded to violet....	5	45.0	1,0 band of C_2 Swan System $C^{12}C^{13}$	4744.7
Head of strong band degraded to violet....	9	52.9	1,0 band of C_2 Swan System $C^{13}C^{13}$	4752.4
Faint absorption line.....	2	59.0	Hale, Ellerman and Parkhurst(4966.50)†	
Strong absorption line.....	4	66.5	$3s^3P_1$—$4p^3P_1$ of C I§	4766.62
Strong absorption line.....	3	69.5	$^3P_1$— $^3P_0$ of C I§	4770.00
Strong absorption line.....	3	72.0	$^3P_2$— $^3P_2$ of C I§	4771.72
Faint absorption line.....	2	89.6		
Faint absorption line.....	2	98		
Head of definite absorption band degraded to red.....	9	4804.1**		
Redward edge of main absorption in this band	8	17.0		
Faint absorption feature.....	3	23.3	Hale, Ellerman and Parkhurst (4823.64)†	
Head of weak band degraded to red or absorption line.....	4	27.9	Hale, Ellerman and Parkhurst (4827.88)†	
Very strong absorption line.....	5	32.2	Hale, Ellerman and Parkhurst (4832.48)†	
Definite absorption feature.....	3	43.7		
Wider weak absorption.....	5	55.2		
Head of very strong band degraded to red..	10	67.1*		
Red end of deep portion of this band.....	2	83		
Strong wide absorption feature.....	1	85.2		
Definite absorption line or band structure...	2	90.3		
Definite absorption line or band structure...	3	95.9		

TABLE I—(*continued*)

Spectral Feature	Number of Plates on which measured	Wave-length	Identification	Laboratory Wave-length
Definite absorption line or band structure...	6	4901.0	Hale, Ellerman and Parkhurst (4901.11)†	
Head of moderately strong band degraded to red.....	10	05.7**		
Centre of the line forming this head.....	3	06.5		
Strong absorption line or band structure....	3	11.0		
Very narrow absorption feature.....	1	14.6		
Strong absorption line or band structure....	3	20.7	Hale, Ellerman and Parkhurst (4920.84)†	
Definite absorption line or band structure..	3	26.3		
Definite absorption line or band structure..	3	31.4		
Definite absorption line or band structure..	3	36.0		
Weaker absorption line or band structure...	2	40.4		
Weaker absorption line or band structure...	4	45.3		
Weaker absorption line or band structure...	3	49.3		
Head of fairly weak band degraded to red..	7	53.7	1,0 band of α System of TiO??	4954.6
Centre of the main "head" absorption.....	3	57.1		
Weak absorption line or band structure....	1	63.7		
Stronger absorption line or band structure..	2	68.7		
Head of very strong band degraded to red..	9	76.9*		
Redward end of very strong absorption....	2	5002.		
Moderate absorption line or band structure.	1	14.6		
Moderate absorption line or band structure.	1	22.8		
Definite absorption line or band structure ..	2	40.0		
Head of band degraded to violet.....	3	99.2	2,2 band of C_2 Swan System	5097.7

TABLE I—(*concluded*)

Spectral Feature	Number of Plates on which measured	Wave-length	Identification	Laboratory Wave-length
Violet edge of next strong bands, 0,0 and 1,1 Swan, or head of band degraded to red.....	2	5107.		
Absorption line or band structure.....	1	10.7		
Head of definite band degraded to violet...	2	30.2	1,1 band of C_2 Swan System	5129.3
Head of very strong band degraded to violet	8	66.3	0,0 band of C_2 Swan System	5165.2
Violet edge of square band or series of absorption lines.....	4	92.2		
Red edge of square band or series of absorption lines.....	3	5211.7	0,0 MgH band, $^2\Pi$, $^2\Sigma$ system.....	5211.0

*—Heads of the strong unidentified bands.
**—Heads of the weaker unidentified bands.
†—See reference 5.
§—These lines are tentatively assigned to the $3s^3P$–$4p^3P$ multiplet of neutral carbon despite the facts that the λλ4762.41 and 4775.87 members were not noted and the excitation potential is 7.45 volts. The features in the spectrum of RY Draconis resemble very closely, on plates with the same instrument, the absorptions identified as this carbon multiplet by Berman (*Ap. J.* vol. 81, p. 369, 1935) in the hot carbon star R Coronae Borealis.

TABLE II

AVERAGE WAVE-LENGTHS AND WAVE-NUMBERS OF HEADS OF THE RED-DEGRADED UNIDENTIFIED BANDS

Number of Plates on which measured	Wave-length	Wave-Number ($cm.^{-1}$)	Wave-Number Intervals	
	Strong Bands			
17	4977.1	20086		
			456	
14	4866.8	20542		
				1460
10	4639.9	21546		
			470	
6	4540.9	22016		
				1426
4	4352*	22972		
			490	
3	4261*	23462		
	Weaker Bands			
13	4906.0	20377		
			434	
10	4804.1*	20811		
				1489
3	4572	21866		
			439	
2	4482*	22305		
				1416
2	4294*	23282		
			(436)	
	(4215)	(23718)		

*Indicates a newly noted band head.

examination of all the material there is no apparent correlation between band intensity and spectral class over this range, despite the fact that from the reproductions of Plate V, alone, there might appear to be.

The following features of the band structure are revealed by the plate. On the upper two spectra just to the red of the head of λ4977, there are four fairly distinct absorptions having the character of lines. They have no definite identification as atomic lines (although the two of shortest wave-length might be the 3^2P-5^2D doublet of NaI), so may be a part of the band structure. In the case of RY Draconis there is a certain structure in the region λ4880 to λ4950, consisting of absorption features about 5A. or 20cm.$^{-1}$ apart. These could conceivably be closely spaced band heads in a sequence. However, on the basis of the vibrational analyses and possible identifications of the carrier molecule to be suggested, they are more likely a partial resolution of the rotational band structure.

Plate V also shows reproductions of two spectrograms of RY Draconis. The upper one covers the region of the bands heretofore known and these are clearly seen. In addition to these, two new faint heads (λλ4804 and 4482) have been measured for the first time. The lower spectrogram (a 17-hour exposure with the two-prism ultra-violet spectrograph) shows the two new strong bands with heads at λλ4352 and 4260, which have the same general character as the strong pairs at λλ4977 and 4867 and at λλ4640 and 4541. Incidentally, the plate illustrates the drastic character of the decrease of intensity from the green to the violet regions in spectra of this type.

The region to the red of λ5200 in the spectrum of RY Draconis has been examined and shows no other red-degraded bands such as those under discussion. Indeed, in the region λ5200 to λ7000, the spectra of the N-type stars showing the unidentified bands do not differ in any appreciable way from those not exhibiting the bands. This observation supports an earlier similar conclusion reached by Sanford. However, there is an absorption feature of apparently rectangular profile extending from λ5192 to λ5211 which appears more definitely in the spectrum of RY Draconis than in other N-type stars. The redward edge probably marks the head of the violet-degraded λ5211 MgH band. From its appearance in the spectrum the short wave-length end at λ5192 could possibly be described as

a red-degraded band head which would fit into the scheme as one of the weaker unidentified bands. The head which should accompany this one (on the basis of the analysis to be given) about λ5314 and which should be somewhat stronger, is not apparent on the plates covering that region. It is therefore very doubtful if the λ5192 feature should be considered as a band head in the weaker system of unidentified bands, so it has not been included in Table II.

The head at λ4954 in the spectrum of RY Draconis, evident on Plate V, agrees fairly well in wave-length with the 1,0 band of the blue-green system of TiO. This band and the 0,0 band at λ5167 are among the strongest TiO bands occurring in stellar spectra of type M. The latter band has not been noted for RY Draconis. Its position immediately adjacent to the strong 0,0 Swan band of C_2 at λ5165 would make it difficult to detect. Also, the two strongest (0,0 and 1,1) bands of the TiO orange system at λλ5598 and 5629 are badly placed for detection in the λ5635 0,1 sequence of the Swan bands of C_2. The weak unidentified band at λ4804 coincides in position with the 3,1 band in the TiO blue-green system. Although it is far from certain that the λ4954 head in the spectrum of RY Draconis is due to TiO, the possibility is worth noting. The mutually exclusive occurrence of TiO bands and C_2 bands serves as the chief distinguishing feature between spectral types M and R-N, so any possible case of coexistence of the bands in one spectrum is of interest. So far, the only celestial source in which both have been identified is the sun.[7]

Discussion

The positions and general arrangement of the unidentified bands suggest that the groups at λλ4977, 4640 and 4352 constitute a $v',0$ progression of bands in a system arising from a transition between the ground state and an upper electronic state of the molecule concerned. In particular, since no strong bands appear to the red of λ4977, the groups would likely be the 0,0, 1,0 and 2,0 transitions.[8]

[7] See, for example, H. D. Babcock, *Ap. J.*, vol. 102, p. 154, 1945.

[8] It seems rather strange that no bands originating on a vibrational level of the lower state with $v'' > 0$ are observed since, for the C_2 Swan system, 0,1 and 0,2 sequences are found. Possibly, however, this could be accounted for by the vibrational quantum of the normal state being appreciably greater than for C_2 or by a predissociation phenomenon.

On this basis, a vibrational analysis may be carried out. At first, attempts were made in various ways to bring all the bands into one vibrational scheme. But there seemed no reasonable way to account for all four heads in each group, with their observed intensities and spacings. Finally, the most likely solution seemed to be that the strong and weak bands constitute two separate systems (electronic transitions) of the same molecule, (the same molecule because as noted below, the doublet splitting is approximately the same for both). This conclusion is concurred in by Dr. G. Herzberg, with whom the problem was discussed and who made several of the suggestions given below relative to the molecule possibly responsible for the bands.

In making a vibrational analysis of a band system, the wave-numbers of the band heads (or preferably, the band origins) are fitted to an expression of the form:

$$\nu(\text{cm.}^{-1}) = \nu_e + [\omega'(v'+\tfrac{1}{2}) - x'\omega'(v'+\tfrac{1}{2})^2 + y'\omega'(v'+\tfrac{1}{2})^3 + \ldots] - [\omega''(v''+\tfrac{1}{2}) - x''\omega''(v''+\tfrac{1}{2})^2 + y''\omega''(v''+\tfrac{1}{2})^3 + \ldots].$$

The single and double primes refer to the upper and lower states, respectively. ν_e is the system origin, ω is the vibrational frequency (in cm.$^{-1}$) for infinitesimal amplitude of vibration for the state concerned, $x\omega$ is a small constant giving a measure of the anharmonicity of vibration and $y\omega$ a smaller constant of the same nature. v' and v'', the vibrational quantum numbers, take the integral values 0, 1, 2, etc. In the present case, only v',0 progressions are available, so only constants for the upper states of the two systems can be determined.

The positions of the strong band heads (upper group of Table II) are reasonably well represented by the expression:

$$\nu(\text{cm.}^{-1}) = \begin{cases} 19335 \\ 19803 \end{cases} + 1498(v'+\tfrac{1}{2}) - 15.5(v'+\tfrac{1}{2})^2.$$

The wave-numbers of the weaker heads (lower group of Table II) are similarly given by:

$$\nu(\text{cm.}^{-1}) = \begin{cases} 19604 \\ 20040 \end{cases} + 1566(v'+\tfrac{1}{2}) - 38(v'+\tfrac{1}{2})^2.$$

In both expressions v' takes the values 0,1 and 2. It can be predicted that the next pair of strong band heads, the 3,0 transition,

would be found about λλ4099 and 4022. None of our plates was strong enough in the violet to show these. The violet component of the 3,0 transition in the weaker system (accompanying λ4294) should occur at λ4215. Its head would doubtless be blended with the usually strong λ4216 violet CN band.

The values of the vibrational frequencies, ω', of the two upper states (1498 and 1566 cm.$^{-1}$) are of the order of the frequencies characteristic of diatomic hydrides and of diatomic molecules having one atom not heavier than those in the first row of the periodic table.

Since each transition gives rise to two widely separated band heads, the electronic levels concerned are probably doublet states. At first sight it might appear that the difference in intensity of the doublets could be taken as evidence favoring the assumption that the splitting in the lower state is considerable, hence that it is a $^2\Pi$ or $^2\Delta$ state rather than $^2\Sigma$. But a puzzling feature is that the longer wave-length band, not the shorter, is the stronger in each case, contrary to normal expectation. So, the intensity ratio cannot be used in support of the assumption that the lower state is $^2\Pi$. If the ground state were close to Hund's coupling case *c*, for which to our knowledge intensity relations have not been derived, it might be the state with the large splitting. As noted above, the doublet separation for both strong and weak band systems being nearly the same ($\sim$ 468 and $\sim$ 436 cm.$^{-1}$ respectively), and the occurrence of the two systems together, make it likely that both arise from the same molecule. For homologous molecules (e.g. BeH, MgH, CaH, ...HgH) with doublet states, the doubling increases with increasing effective mass. For example, the doubling for a $^2\Pi$ state goes from 2 cm.$^{-1}$ for BeH to 3684 cm.$^{-1}$ for HgH. The doubling for the unidentified systems ($\sim$ 450 cm.$^{-1}$) is about that found for hydrides of elements in the fourth row of the periodic table.

Among the likely molecules as carriers of the unidentified bands are TiH and FeH. The spectra of neither of these molecules are known[9] but both should give rise to systems of even multiplicity since they contain an odd number of electrons.

For TiH in particular, certain predictions can be made on the basis of our knowledge of the spectra of the homologous CH and

[9]Heimer (*Naturwiss.*, vol. 24, p. 491, 1936) reported a $^1\Sigma$, $^1\Sigma$ type band with origin at λ4288 as being due to FeH. This cannot be correct since FeH bands would be of even multiplicity.

SiH molecules. Among the predictions are the following, and except for the relative intensities of the component bands pointed out above, none is at variance with the known data on the unidentified systems.

1. The ground state would be $^2\Pi$ and the doublet splitting would be of the order found (~ 450 cm.$^{-1}$).

2. The next two states above the normal $^2\Pi$ state would be $^2\Delta$ and $^2\Sigma$ states. These would be the analogues of the upper states of the strong $^2\Delta$, $^2\Pi$ λ4315 band and the weaker $^2\Sigma$, $^2\Pi$ λ3889 system of CH. It does not seem unlikely that for TiH these states should be close together as called for by the occurrence of the strong and weak unidentified bands in the same wave-length region. Furthermore, these transitions would account satisfactorily for the observed difference in intensity of the two systems. Also, the variation in doublet separation for the stronger bands and its constancy for the weaker system are in accord with this assignment.

On current ideas, the N-type stars have relatively little oxygen but an abundance of carbon. Hence it would seem rather natural that TiH bands would occur in company with those of carbon compounds if the TiO bands do not occur for lack of oxygen. The case for TiH seems sufficiently plausible that Dr. Herzberg has undertaken to try to produce the spectrum of this molecule in the laboratory.

The case for FeH cannot be so fully developed, but it can be said that FeH bands should exhibit even multiplicity with splitting of the order of that shown by the unidentified bands and should have vibrational frequencies (ω) much like those found. Also, the relatively high abundance of iron in stellar atmospheres (about the eighth most abundant element by mass) is too well known to require additional emphasis.

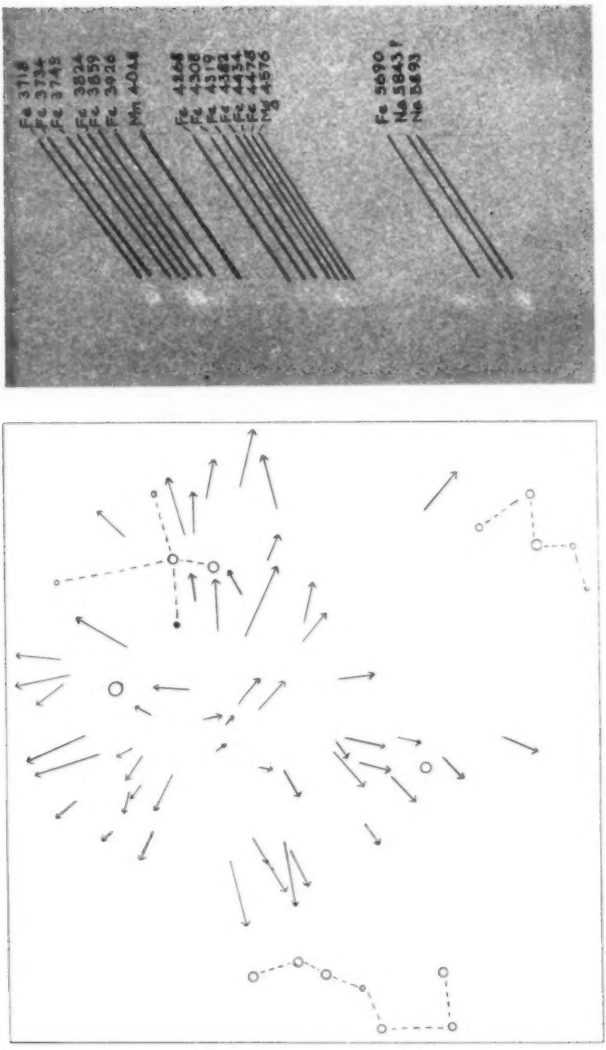
Only TiH and FeH have been mentioned specifically but it should be noted that although they are among the most likely, they are by no means the only molecules that could be responsible for the unidentified bands.

From the above discussion two matters previously mentioned remain puzzling, (1) the non-occurrence of any bands from vibrational levels above $v'' = 0$ for the normal state and (2) the relative intensities of the pairs of bands. Until these are explained, the analysis given must be considered tentative. It is hoped, however,

that the discussion may stimulate further work, particularly in the laboratory, on the unidentified bands.

In conclusion the kind co-operation of the late Dr. A. B. Wyse of the Lick Observatory in securing two spectrograms of RY Draconis is gratefully acknowledged as is also the helpful correspondence with Dr. G. Herzberg of the Yerkes Observatory.

Dominion Astrophysical Observatory,
Victoria, B.C.
August, 1946.



GIACOBINID METEORS

Above—Spectrum
Below—Trails plotted at York Mills

COMMUNICATIONS
FROM THE
DAVID DUNLAP OBSERVATORY
Number 13

OBSERVATION OF THE GIACOBINID METEORS AT THE DAVID DUNLAP OBSERVATORY

By John F. Heard

(With Plate VI)

A programme of visual and photographic observations of the Giacobinid meteor shower of October 9-10, 1946, was planned and carried out at the David Dunlap Observatory, Richmond Hill and at a supplementary station at York Mills, about nine miles to the south. Early on the 9th weather conditions promised to be more favourable to the west, so during the day the equipment was dismantled and packed in cars with a view to setting up two observing stations in the neighbourhood of Wingham or Goderich. However, by early evening the forecaster believed that the chances of clear skies were better in the Toronto district and plans were again changed. Actually, cirrus haze beginning just after sunset and thickening gradually to overcast condition at 22:15 seriously hampered the programme and caused us to miss altogether the sharp maximum at about 22:45. The results of the programme are accordingly limited.

Visual Observations. At the Observatory between 19:30 and 22:15 E.S.T. 231 meteors were observed visually and timed accurately; of these 157 were plotted. At the York Mills station between 20:40 and 22:47 E.S.T. 55 meteors were observed and timed and 50 of these were plotted as shown in the accompanying illustration.

Photographic Observations. At the Observatory a battery of four cameras was mounted behind the Observatory's rotating shutter designed by Millman a few years ago. These cameras were of focal ratio F/4.5, had focal lengths of 5, 6, 6¼, and 8 inches and covered plates of sizes 3¼ x 4¼ for the first two and 4 x 5 for the last two. Each of the 5-inch and 6¼-inch cameras was fitted with a 30-degree prism to obtain spectra. The battery of cameras was arranged to cover an area of the sky about 50 degrees x 70 degrees. The centre

of this field was maintained approximately at the predicted position of the radiant by altering the mounting after each exposure. Exposures were restricted to 20 minutes or less on account of the moonlight. Seven exposures were obtained with each camera between 19:30 and 22:15 E.S.T.

At the York Mills station an F/4.5, 2-inch focal length camera was used. It was aimed at a point about 10 degrees from the radiant towards the north point on the horizon in the hopes of recording some of the same meteors as at the Richmond Hill station for purposes of height determination. Seven exposures of about 15 minutes duration were made.

Eastman 103a0, Eastman Tri-X Pan and Ansco Triple-S Pan emulsions were used.

All that was obtained from the photographic programme was four faint trails, one or two of them doubtful, one (doubtful) partial spectrum and one reasonably good spectrum. This latter is very short, being the result, apparently, of a short-lived burst of brightness in the meteor. This spectrum, reproduced here, has been measured and, with the help of prints of several Giacobinid spectra kindly loaned by Peter M. Millman of the Dominion Observatory, multiplets have been identified as indicated on the reproduction. This spectrum follows the pattern of other Giacobindis, as observed by Millman*, namely, very strong sodium D line, fairly strong multiplets of iron at low excitation, other weaker multiplets due to neutral magnesium, mangaese and sodium. Neutral calcium at 4226, fairly strong on some of Millman's spectra, is not seen on ours.

Those taking part in the observations were Frank S. Hogg, Helen S. Hogg, Ralph E. Williamson, Dorothy Williamson, Ruth J. Northcott, John F. Heard, Gerald Longworth, Richard Tanner, John Horwood, Jack Grant, Carson Whelan and Margaret Whelan.

*Harvard College Observatory Announcement Card No. 782, Nov. 20, 1946.

Richmond Hill, Ontario,
April 26, 1947.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

Halley and the Brightness of Venus

THE third brightest object in our heavens is the planet Venus. In view of its importance, it is interesting to enquire at what point in its orbit will it reach its maximum brilliancy as seen from the earth? As Venus recedes from the earth, at what point is the increase in illuminated area offset by the decrease in apparent diameter of this planet, so that the brilliance fades? Most of us have learned that this point of greatest brilliancy, which last occurred on December 23, 1946, comes when Venus has the phase of a 5-day moon.

Apparently the first person to solve this geometrical puzzle was the famous Edmond Halley. His attention was drawn to the problem by the fact that Venus had been rather conspicuously visible in the day time in the region of London. He worked out the mathematics of the relations between the sun, earth, and Venus, to show at what point in the orbit of Venus she would attain maximum brilliance as viewed from the earth. Halley came to the conclusion that the point of maximum brilliance was about 40 degrees on either side of inferior conjunction. A computation with the elements of the orbit of Venus as accepted to-day gives 39°.8 as the value, astonishingly close. As well as admiring the cleverness of Halley in thinking through the explanation for the greatest brilliance of Venus, we marvel at his conclusion regarding the fixed stars, that their apparent diameters must be "inconceivably small."

His analytical development and solution of the problem are substantially those still used in current textbooks. His geometrical contruction is very simple, but as far as the writer is aware, has not appeared in any astronomical book for many years.

We reprint here his article from *The Philosophical Transactions* abridged, vol. 4, pp. 300-302, 1721.

An Account of the Cause of Venus being seen in the Daytime

by Dr. E. Halley

XXVIII. The late Appearance of *Venus* in the *Day time*, for many Days together, was generally taken Notice of about *London*, and elsewhere; and by some reckoned to be Prodigious. This put me upon the Enquiry, how it came to pass, that at that time the *Planet* should be so plainly seen by Day; whereas she rarely shews her self so, unless to those, who know exactly where to look for her. To resolve this, the following Problem arose, *viz.* To find the Situation of the *Planet* in respect of the *Earth*, when the *Area* of the illuminated Part of her Disk is a *Maximum*.

To investigate this *Maximum*, I found it requisite to assume the following Lemmata. I. That the visible *Areas* of the Disk of the same *Planet*, at differing Distances, are always Reciprocally as the Squares of those Distances; which is evident from the first Principles of Opticks. II. That the *Area* of the whole Disk of the *Planet* is to the *Area* of the enlightned Part thereof, as the Diameter of a Circle to the Versed-Sine of the exteriour Angle at the *Planet*, in the Triangle, at whose Angles are the *Sun*, *Earth*, and *Planet*. III. That in all plain Triangles, four times the Rectangle of the Sides containing any Angle, is to be the Excess of the Square of the Sum of the Sides above the Square of the Base, as the Diameter is to the Versed-Sine of the Complement of the Contained Angle to a Semicircle, which I call the exteriour Angle: This is a new Theorem of good use in *Trigonometry*, and is easily to be proved from the *12th* and *13th* of the II. *Elem. Euclid*.

This premised, putting m for the Distance of the *Sun* and *Earth*, and n for that of the *Sun* and *Venus*, and x for the Distance of the *Earth* and *Venus*, or the third Side of the Triangle which we seek; by the third *Lemma*, $4\,n\,x$, will be to the Excess of the Square of $n + x$ above the Square of m, as the *Area* of the whole Disk of *Venus* to the *Area* of the Part enlightned; and by the *first Lemma*, the *Area's* of her whole Disk, are at all times as the Squares of x reciprocally; whence the Quantity

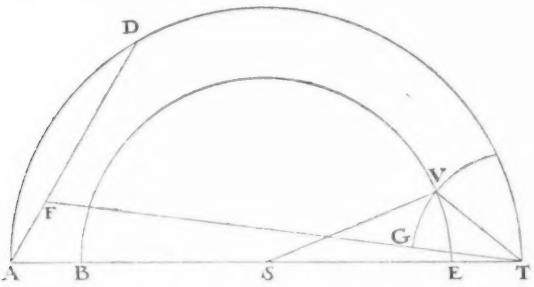
$$\frac{n\,n + 2\,n\,x + x\,x - m\,m}{4\,n\,x^3}$$

will in all Cases be proportional to the Area of the enlightned Part.

Now that this should be a *Maximum*, it is required that the Fluxion thereof be equal to o, or that the Negative Parts thereof be equal to the Affirmative; that is, that $2\,n\,\dot{x} + 2\,x\dot{x} \times 4\,n\,x^3 = 12\,n\,x^2\,\dot{x} \times n\,n + 2\,n\,x + x\,x - m\,m$; and dividing all by $4\,n\,x^2\,\dot{x}$, the Equation becomes $2\,n\,x + 2\,x\,x = 3\,n\,n + 6\,n\,x + 3\,x\,x - 3\,m\,m$. Consequently $3\,n\,n + 4\,n\,x + x\,x = 3\,m\,m$, and therefore $x = \sqrt{3\,m\,m + n\,n} - 2\,n$.

From hence a ready and not inelegant Geometrical Construction becomes obvious; for with the Center S, and Radius $ST = m$, describe the Semicircle $T\,D\,A$; and with the same Center and Radius $S\,E = n$, the Semicircle $E\,V\,B$; which two Semicircles shall represent the Orbs of the *Earth*, and *Venus*. Then

make the Chord $A\ D$ = to the Radius $S\ T$, and from D towards A, lay off $D\ F = S\ E$; draw $T\ F$, and thereon place $F\ G = B\ E = 2\ n$, and with the Centre T



and Radius $T\ G$ describe the Arch $G\ V$, cutting the Semicircle $B\ V\ E$ in V; and draw the Lines $S\ V$, $T\ V$; I say the Triangle $S\ T\ V$ is similar to that, at whose Angles are the *Sun*, *Earth*, and *Venus*; at the time when the *Area* of the inlightned Part of that Planet's Disk, as seen from the *Earth*, is greatest. How this Geometrical Effection follows from the Equation is too evident to need repetition.

In consequence then of this Solution, I find this *Maximum* always to happen, when the *Planet* is about 40 degrees distant from the *Sun*; and the times thereof about the middle between her greatest Elongations on both Sides from him, and her retrograde Conjunctions with him; when little more than a quarter of her visible Disk is Luminous, and resembling the Moon of about 5 days old; and tho' her Diameter is at that time but 50 Seconds, yet she shines with so strong a Beam, as to surpass the united light of all the fixt Stars that appear with her, and casts a very strong Shade on the Horizontal Plain, whereon they all shine: an irrefragable Argument to prove, that the Disks of the Fixt Stars are inconceivably small, and next to nothing; since shining with a *Native* Light, so many of them do not equal the *reflex* Light of one quarter of a Disk of less than a Minute Diameter.

In this Situation *Venus* was found in *July* last, on the Tenth Day; about which time, when the *Sun* grew low, she was very plainly seen in the Day time, for several Days together; as she might have been in the Mornings, about the latter End of *September*. But this, arising from the Causes we have now shewn, is nothing uncommon; for every Eighth Year it returns again, so that the *Planet* may be seen on the same Day of the Month and Hour, very nearly in the same Place.

Lastly it may not be amiss to note, that the Equation $x = \sqrt{3\ m\ m + n\ n} - 2\ n$ has a Limit; for if n be equal to $\frac{1}{4}\ m$, the Point V will fall on B; and the whole Disk of a Planet at that Distance from the *Sun* would be the *Maximum*, *viz.* when in its superiour Conjunction with the Sun. And the like if n were less than $\frac{1}{4}\ m$; the Arch $G\ V$ in such Case not intersecting the Semicircle $B\ E$.

In modern terminology, Halley's three Lemmas become:

Lemma I. Area of the visible disc varies as $1/x^2$

Lemma II. Area of whole disc: area illuminated: : 2: $(1 + \cos \angle S\,V\,T)$ where $\angle S\,V\,T$ is the elongation of the earth from the sun as seen from the planet.

Lemma III. $4\,n\,x : (n + x)^2 - m^2 : : 2: (1 + \cos \angle\, SV\,T)$.

Then neglecting the eccentricity of the orbit of Venus,
Brightness, $B \propto (n^2 + 2\,n\,x + x^2 - m^2) / 2\,n\,x^3$.
For condition maximum brightness Halley's "Fluxion" becomes

$$dB\,/dx = 0 = x^2 + 4\,n\,x + 3\,(n^2 - m^2)$$

whence $$x = \sqrt{3\,m^2 + n^2} - 2\,n$$

His "not inelegant Geometrical Construction," illustrated in the diagram, depends on making the angle $D\,A\,T$ equal to sixty degrees.

By construction, $A\,D = m$; $D\,F = n$; $A\,F = m - n$; $A\,T = 2\,m$; $F\,G = 2\,n$

$$\begin{aligned} F\,T^2 &= A\,F^2 + A\,T^2 - 2\,A\,F.\,A\,T \cos \angle D\,A\,T \\ &= 3\,m^2 + n^2 \\ x = T\,G &= F\,T - F\,G \\ &= \sqrt{3\,m^2 + n^2} - 2\,n, \end{aligned}$$

which satisfies the condition for maximum brightness of the planet, as determined above from fluxions.

Readers who wish to hunt for Venus in the daytime are referred to the article by F. K. Dalton in this JOURNAL in February, on Interesting Attachments for the Telescope.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Fire-Walking

In the issue of this Journal for October, 1946 (p. 323), is a *Note* bearing the heading "Why doesn't the fire burn?" and containing brief descriptions of the fire-walking ceremony observed recently in the Pacific islands.

In answer to the above question the present writer received from his good friend Albert G. Ingalls a copy of *Scientific American* for March, 1939, in which is a full description and discussion of fire-walking performances. As we all know, Mr. Ingalls is one of the editors of this magazine, which has devoted much effort to find out the true solution of some physico-psychological questions which continually crop up.

The article referred to is by Mr. Ingalls and it was read by the present writer when it was published, but, like some other matters, it had escaped from his memory. After a short introduction, a summary is given of the experience of S. P. Langley and Percival Lowell, and then follow several letters which had been written to the magazine giving interesting reports of observations made in various parts of the world.

The University of London Council for Psychical Research conducted some fire-walking experiments right in the city of London. Two oriental "magicians" undertook to walk on a bed of glowing embers at surface temperatures actually measured to be from 1060 to 1470 degrees Fahr., and a number of English volunteers did the same thing. Full details, with pictures, are given, and the general conclusion is that there is no magic trick and no deception but that the feat is honestly performed.

The precise reasons why the bare feet of the walkers are not burned were not so definitely determined but they seem to be: (1) The hot stones (used in the Pacific islands) and the hot coals from burning wood (generally employed in the Hindu performances) are poor conductors of heat. If these were replaced by masses of copper, iron or other metals, at equally high temperatures, there would be serious burns. (2) The contact of the soles of the feet

with the hot stones or embers is very brief—a fraction of a second. (3) The weight of the performer and also the way his feet are placed on the hot materials are important matters. Stout, heavy persons should not attempt fire-walking. (4) It would appear that if the performer has had previous experience and has self-confidence he is more likely to succeed. An "ecstatic" state of mind may prevent him from feeling any pain.

C. A. C.

The Royal Astronomical Society of Canada

OFFICERS FOR 1946

Honorary President—The Honourable George A. Drew, Prime Minister and Minister of Education for the Province of Ontario.
President—A. E. Johns, Ph.D., Hamilton, Ont.
First Vice-President—H. Boyd Brydon, Victoria, B.C.
Second Vice-President—J. W. Campbell, Ph.D., Edmonton, Alta.
General Secretary—E. J. A. Kennedy, 3 Willcocks St., Toronto 5
General Treasurer—J. H. Horning, M.A., Toronto
Recorder—H. W. Barker, Toronto
Librarian—D. W. Best, D.D., Toronto
General Council—S. C. Brown, Toronto; G. E. Campbell, M.A., Hamilton, Ont.; W. G. Colgrove, M.A., B.D., London, Ont.; G. Harper Hall, Montreal, P.Q.; Cyril B. Hallam, B.A., Windsor, Ont.; Helen S. Hogg, Ph.D., Toronto; P. H. Nadeau, M.Sc., Quebec; Robert Peters, Victoria, B.C.; Andrew Thomson, M.A., Toronto; M. M. Thomson, B.A., Ottawa; H. D. Smith, Ph.D., Vancouver, B.C.; ———— Edmonton, Alta., and Past Presidents—F. S. Hogg, Ph.D., and A. Vibert Douglas, M.B.E., Ph.D.; also the presiding officer of each centre.

TORONTO CENTRE

Honorary President—C. A. Chant, Ph.D. *President*—H. W. Barker
First Vice-President—A. R. Clute, K.C. *Second Vice-President*—Frank S. Hogg, Ph.D.
Secretary—Tracy D. Waring, 44 Rose Park Drive, Toronto 12
Treasurer—T. H. Mason *Recorder*—Frederic L. Troyer
Council—J. F. Heard, Ph.D.; George T. Dale; R. S. Duncan; S/L P. M. Millman; J. H. Horning, M.A.; H. G. Duncalfe; Helen S. Hogg, Ph.D.; C. A. Crook; W. R. Sherrick; and Past Presidents—J. R. Collins; E. J. A. Kennedy; S. C. Brown; Rev. D. W. Best; Miss R. J. Northcott, M.A.

OTTAWA CENTRE

Honorary President—T. L. Tanton, Ph.D. *President*—Hoyes Lloyd, M.A.
First Vice-President—Fäl M. M. Thomson, B.A.
Second Vice-President—R. J. McDiarmid, Ph.D.
Secretary—W. S. McClenahan, B.A., Dominion Observatory, Ottawa
Treasurer—F. W. Matley, Esq.
Council—Miss C. B. Hicks, B.A.; R. G. Madill, B.A.; A. H. Miller, M. A.; Valmer A. Nixon; C. B. Reilly, K.C.

HAMILTON CENTRE

Honorary President—W. T. Goddard *President*—Rev. E. F. Maunsell
Vice-President—T. M. Norton,
Secretary-Treasurer—G. Murchie; 77 Fennell Ave. W. *Curator*—Mr. G. E. Campbell, M.A.
Council—Dr. W. Findley; Dr. A. E. Johns; W. D. Stewart, B.A.; D. G. Burns; F. S. Sisman; W. S. Mallory, M.A.; H. B. Fox; J. W. McCallion, B.A.; F. H. Butcher, B.A.; J. R. Graham; F. Schneider; V. Taylor.

WINNIPEG CENTRE

Honorary President—Prof. L. A. H. Warren *President*—Miss O. A. Armstrong
First Vice-President—A. P. Morse *Secretary*—C. G. Card, 1197 Dominion St.
Treasurer—C. D. Dorsett *Press Secretary*—L. W. Koser
Council—L. J. Crocker; Mrs. J. Norris; R. A. Storch; D. R. P. Coats; L. T. S. Norris-Elye; V. C. Jones.

MONTREAL CENTRE

Honorary President—Mgr. C. P. Choquette *President*—Henry F. Hall
Vice-President—F. J. DeKinder
Secretary—J. W. Duffie, 582 Mercille Ave. St. Lambert, Mtl. 23
Treasurer—A. R. MacLennan *Recording Secretary*—Miss I. K. Williamson
Director of Observations—DeLisle Garneau *Librarian*—C. M. Good
Council—Dr. D. E. Douglas; G. Harper Hall; F. W. Henshaw; Prof. A. H. S. Gillson; F. T. Matthews; F. P. Morgan; R. Russell Paterson; Dr. W. Bruce Ross; Dr. A. Norman Shaw; and Past President—Dan. P. Gillmor, K.C.

VICTORIA CENTRE

Honorary President—R. M. Petrie, Ph.D. *President*—K. O. Wright, Ph.D.
First Vice-President—A. McKellar, Ph.D. *Second Vice-President*—W. R. Hobday
Secretary-Treasurer—Miss J. K. McDonald, B.Sc., Dom. Astrophysical Observatory
Recorder—Lt.-Cmdr. A. M. P. Scaife *Librarian*—Miss V. Langworthy
Council—H. J. Chalk; Mrs. J. R. Noble; H. A. Reid; Dr. J. S. Stevenson; M. Trueman; Mrs. C. S. Yarwood

LONDON CENTRE

Honorary President—Dr. H. R. Kingston *President*—Dr. R. H. Cole
Vice-President—Dr. A. J. Watt *Secretary-Treasurer*—A. Emsley, 831 Richmond Street
Council—W. E. Shales; Dr. L. M. Spratt; Dr. G. Calder; Chas. Hanson; Mrs. D. M. Hennigar

VANCOUVER CENTRE

Honorary President—Dr. G. M. Shrum *President*—N. Barton
Vice-President—Dr. K. C. Mann *Recording Secretary*—Earl M. Price
Corresponding Secretary—Robert S. Codrington *Treasurer*—Miss G. W. Owen
Council—Mr. N. D. B. Phillips; Mrs. C. A. Rogers; Mrs. L. Anderson; Mr. A. Outram; Dr. O. Buch; Mr. M. T. Spence; Lt. Comm. C. A. McDonald.

(Continued at bottom of next page)

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
1890-1946

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton, London and Windsor, Ontario; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as over 1,000 members of these Canadian Centres, there are over 400 members not attached to any Centre, mostly resident in other nations, while some 50 additional institutions or persons subscribe to our publications.

The Society publishes a monthly "Journal" containing about 500 pages and a yearly "Observer's Handbook" of 80 pages. Single copies of the "Journal" or "Handbook" are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 3 Willcocks St., Toronto.

The Society has for Sale:

Reprinted from the "Journal" of the Royal Astronomical Society, 1936-1944.

The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

General Instruction for Meteor Observing, (revised 1940) by Peter M. Millman, 24 pages; **Price 15 cents postpaid.**

A Yoke Mounting for the Six-inch Telescope, by H. Boyd Brydon, 8 pages; Price 10 cents postpaid.

Setting Up and Adjusting the Equatorial Reflecting Telescope, by H. Boyd Brydon, 25 pages; Price 25 cents postpaid.

In quantities of ten or more copies, a discount of 20 per cent will be allowed. Send Money Order to 3 Willcocks St., Toronto.

(Continued from previous page)

EDMONTON CENTRE

Honorary President—J. W. CAMPBELL
President—M. WYMAN
Vice-President—F. C. BLOWER
Secretary—E. H. COWAN, University of Alberta
Treasurer—MISS A. M. F. SMITH
Librarian—E. S. KEEPING
Social Hostess—MISS M. BOWMAN
Council—A. J. COOK; D. B. SCOTT; H. J. MONTGOMERY; T. M. CARSCADDEN.

CENTRE DE QUEBEC

Patron—MGR. FERDINAND VANDRY, P.A., V.G., Recteur de l'Université Laval
Président Honoraire—ARTHUR AMOS, I.C.
Président—JEAN-CHS. MAGNAN, B.A., B.S.A.
1er Vice-Président—LUCIEN POULIOT, C.G.A.
2ème Vice-Président—LIONEL LEMIEUX, B.A., LL.L.
Secrétaire—PAUL-H. NADEAU, M.Sc., 275 rue St. Cyrille
Trésorier—LIONEL GALLICHAN
Membres du Conseil—M.M. L'ABBÉ ROSARIO BENOIT; L'ABBÉ EMILIEN GAUTHIER; ALBÉRIC BOIVIN, B.Sc.Ap.; M.-LOUIS CARRIER, I.C.; GEO.-E. GAGNÉ; CHARLES-A. GIROUX; LLOYD MCWILLIAMS, EL.E.; OSCAR VILLENEUVE, I.F.

WINDSOR CENTRE

President—CYRIL B. HALLAM, B.A.
Vice-President—D. C. BAWTENHEIMER
Past President—C. H. MONTROSE, B.Sc.
Treasurer—CHARLES A. BELL, B.A.
Secretary—RUSSELL WARWICK, B.A., 1587 Moy Ave., Windsor, Ont.
Council—MRS. MARGARET BACK; JUDGE J. J. COUGHLIN; E. J. EDWARDS; JACK EVZOVITCH, B.S.E.E.; W. ALMON HARE, B.A.Sc.; F. W. C. JONES; E. M. KREBSER; GREGORY RAWLINGS, B.A.; W. A. ROBERSON; LORNE R. ROGERS, B.A.; G. F. SPRACKLIN; GORDON E. TURNER.